THE VARIABLE STARS *TV, TW, TX* CASSIOPEIÆ AND *T* LEONIS MINORIS.

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The four Algol variable stars *TV, TW, TX* Cassiopeiæ and *T* Leonis Minoris have been under observation by the writer for the last three years with the polarizing photometer attached to the 23-inch equatorial of the Princeton Observatory.

The total number of measures made on the four systems is over 35,000, distributed among the four stars as follows, *TV* 9,920, *TW* 13,728, *TX* 8,486 and *T* Leonis 3,792. The light curves of the first three are well defined, while the observations on the last system are not so complete. The periods of the light variation with the exception of *TV* Cass. have been determined from my visual observations combined with photographic measures kindly sent me by Professor Pickering, of Harvard.

The systems will be discussed in slightly different order than the above, the more important left to the last.

The system *TW* Cass. has been observed by other astronomers, and notes published pronounced it as irregular in its variation, later Zinner found it regular in its variation and of the Algol type with a period $1^d\ 10^h\ 16.6^m$. From the discussion of the Princeton observations I found that the period was double the published period and instead of one eclipse there were two differing by 0.05 magnitude. The double period is confirmed by the three observed phenomena, 1st, the difference in depth of the two minima of 0.05 mg.; 2d, the interval from primary eclipse to secondary is 7.8 minutes longer than from secondary to the following primary; 3d, the primary eclipse is 36 minutes longer in duration than the secondary. It is from the knowledge of the last two facts that we are able to determine both components of the eccentricity—the quantities *e* and (longitude of periastron). The period is 2 days, 20 hours, and

33.6 minutes and the two eclipses have a depth of 0.62 mg. and 0.57 mg. respectively. From a discussion of the light curve following the theory as outlined by Professor Russell in *A. J.*, 36, 5; 36, 1 results were obtained giving the dimensions of the system in terms of the radius of the orbit. It was found that the two stars were of nearly the same size and had the same surface brightness.

In the case of *T* Leonis Minoris as in *TW* Cass. we have two minima, they are however of very different depth, the primary having a loss of 2.46 magnitudes while the secondary has only 0.05 magnitudes. The period is 3 days, 0 hours, 28 min., and 38.0 sec., and is accurately known. Combined with the visual observations I have used the Harvard photographic measures as far back as 1889, and have been able to establish a definitive period. The observations are not so complete as in the other systems, the length of the period being so nearly three days; also weather conditions at special times have entered largely into this.

From a study of the light curve along the lines of the eclipsing theory it has been found that the stars are of nearly the same size but are very different in surface brightness, the ratio being 1 : 18.

The third system *TV* Cass., whose period, $1^d\ 19^h\ 30^m\ 11.7^s$, has long been known, having been observed by Ashbury and Yendell, was placed under observation in October, 1913, at Dr. Shapley's suggestion. At that time nothing was known about the secondary eclipse. From my observations it was found that a secondary eclipse of 0.09 magnitude did really exist, coming 21 minutes before the time of mid period. The orbit of the system like that of *TW* Cass. is eccentric, but in this case the components of the eccentricity can not be separated.

In the two previous stars it was found from the light curve that the stars were of constant brightness between eclipses. The light curve of *TV* Cass. is somewhat different as there seems to be a gradual rise in the curve between primary and secondary eclipse which corresponds to an increase in brightness of the system. The explanation is, that the radiation of the bright star on the side of the fainter one as they approach the time of secondary eclipse tends to brighten its surface and thus give rise to the phenomenon observed in the light curve. From a study of the light curve it was found

that the fainter star was twice as bright on one side as the other. The stars are nearly equal in size with a ratio of surface brightness of 1 : 5.5. In this system the depth of the primary eclipse is 1.05 magnitudes and its duration a little over 6 hours.

The last system, *TX* Cass., is the most interesting of the four stars treated here. It was announced some years ago as being an irregular variable; later its period was given by Zinner with the note, that the period was probably changing. It was partly on account of these published notes that a thorough study of the light curve of the star was carried out. Owing to the nature of the variation the star has proved to be a difficult system for photometric study. The eclipses, primary and secondary, which undergo a loss of light of 0.54 and 0.33 magnitudes respectively and last over 18 hours, are difficult to observe, in fact it is impossible to obtain a complete minimum on any one night even during the long nights of winter. The Harvard photogarphic measures have again proved to be of extreme value and by combining them with the visual observations I was able to establish a definitive peroid. The period is 2 days, 22 hours, 14 min., and 41.7 sec.

In the systems so far discussed the stellar disc was considered of uniform surface brightness. Assuming this to be the case with the system *TX* Cass. it was found that the observations could not be represented at all satisfactorily; the deviations were in many cases three times the probable error. On the other hand assuming the stellar discs to be similar to the sun bright at the center and decreasing in brightness toward the edge, a very satisfactory representation of the observations was found. The hypothesis of darkened discs seems to be the correct one as it is confirmed by the nature of the eclipses; the secondary eclipse is total with a constant phase of six hours while the primary eclipse has no constant phase and the curve is distinctly round bottomed showing that the variation is continuous. This condition would exist with darkened discs in case of an annular eclipse, and since the secondary is total our natural and legitimate conclusion is that the primary is annular. The system *TX* Cass. seems to offer very strong evidence in support of darkening toward the limb in stellar systems.

The light between eclipses does not remain constant; the light curve is distinctly bowed up, showing the stars are elliptical in shape and have their greatest brightness when we see them broad side on. This is the condition midway between eclipses. From the study of the light curve it was found that the stars are very different in size, with the stars nearly of the same brightness having a ratio of 1 : 1.5. The ellipticity of the stars can best be shown by giving their dimensions expressed in terms of the radius of the orbit.

	Major Axis.	Minor Axis.
Big star	$a_1 = 0.567$	$b_1 = 0.519$
Small star	$a_2 = 0.295$	$b_2 = 0.270$

The stars in this system are very close together.